ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Competitive Ability and Biological Efficiency of Annual Mixtures.

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ABSTRACT

The results of studies conducted in the three-factor field experiment in 2015-2017 at the experimental field of the FSBSI «Penza Research Institute of Agriculture», in assessing the competitiveness and biological effectiveness of cultivating mixed agrophytocenoses are presented. The studies were carried out on leached medium-loamy black soil, with high and increased provision of accessible forms of macroelements, according to generally accepted methods. We studied annual fodder crops common in the region of research - Sudan grass, corn and low-spread - sawa millet, foxtail millet, amaranth and white sweet clover. The rates of seeding of leguminous and related components are 75 + 40%, 55 + 55%, 40 + 75% of the total. Doses of mineral fertilizers $N_{45}P_{45}K_{45}$ and $N_{60}P_{60}K_{60}$ were studied as the background of nutrition. The optimal components for white clover are corn and foxtail millet. The high biological efficiency of cultivating mixtures of white sweet clover with corn and amaranth at a seed rate of 40 + 70% (from the full seeding rate) against the background without the use of mineral fertilizers was found (LER was 1.31 and 1.20).

Keywords: mixtures, competitive ability, biological efficiency, seed rate, food background.

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ISSN: 0975-8585

INTRODUCTION

Providing agricultural animals with high-grade fodder is the most important task to reduce the cost of livestock products and increase the profitability of its production. The cultivation of mixed agrophytocenoses of fodder crops is the most promising way of obtaining all types of feed, which allows to increase the nutritional value of rations and increase the stability of yields from year to year. When growing mixed crops of annual bluegrasses and leguminous grasses, a biologically complete mixture is formed directly in the field, the energy and protein nutrient content of which is 20-70% higher than that of one-species crops, the sugar-protein ratio in feeds improves significantly. Having different amino acid, vitamin and carbohydrate composition, cultures in mixed crops mutually complement and enrich each other in nutritional value, and, therefore, are more fully absorbed by the animal organism [1, 3, 8, 10].

The tendency of aridization of the Middle Volga region that has been emerging in the last decade makes it necessary for the future to search for crops that are well resistant to short-term droughts and capable of providing a high yield of green mass, haylage, and seeds. Among the annual fodder crops, in addition to Sudan grass and corn, which are widespread in the region, it is necessary to single out new grain-crops - foxtail millet and sawa millet [5, 12]. As a leguminous component, annual white sweet clover is perspective. It is well adapted to local soil and climatic conditions, has high productivity, protein content, drought resistance, nitrogen-fixing ability [2, 11].

However, insufficient study of new cultures in the region makes it difficult to form highly productive mixed agrophytocenoses without studying the competition of species among themselves, the dependence of some species on others, the presence of complementary species [6, 7]. The mutual relations of plants in mixed crops can be very diverse: from sharp competition to mutual assistance. It depends on the biological nature of different plant species and on the conditions of the environment. In view of these parameters, it is possible to identify and select cultures that most fully use the areas of joint living. In such agrophytocenoses, plants form several layers, their leaves are in the most favorable position, which contributes to the effective use of solar energy for crop formation [4].

MATERIALS AND METHODS

Experimental work was carried out in 2015-2017 at the experimental field of FSBSI «Penza Research Institute of Agriculture» in the years with contrasting weather conditions. The year 2015 was not sufficiently moistened in May and August, excessively moistened in June-July with a hydrothermal coefficient (HTC) of May-August period of 0.77 units. In 2016 it was characterized by an excess of daily average temperatures and precipitation in all months of vegetation with the HTC of 1.11 units, 2017 - characterized by excessively moistened May, not sufficiently moistened in June, July and dry August. HTC of the period May-August - 0.71.

The soil of the experimental site is leached heavy loam black soil with humus content in the plowing layer of soil - 6.3%, pHsol - 5.8, with a high content of easily hydrolyzable nitrogen - 78 ... 90, an increased content of available phosphorus - 156 ... 174, exchange potassium - 123 ... 132 mg per 1 kg of soil.

To solve the tasks posed, a three-factor field experiment was laid down according to the following scheme:

Factor A - components of the mixture: 1. White sweet clover + Sudan grass; 2. White sweet clover + corn; 3. White sweet clover + Foxtail millet; 4. White sweet clover + amaranth; 5. White sweet clover + sawa millet.

Factor B - norm of sowing of white sweet clover and accompanying component: 1. 75 + 40%; 2. 55 + 55%; 3. 40 + 75% (sowing rates are presented as a percentage of recommended for pure crops).Factor C - background of mineral nutrition: 1. Control (without fertilizers); 2. $N_{45}P_{45}K_{45}$ (background 1); 3. $N_{60}P_{60}K_{60}$ (background 2).

The repetition is threefold, the area of the plots of the first order is 45 m2, of the second - 15 m2, of the third - 5 m2. Method of sowing - alternating rows of sweet clover and accompanying culture (15 cm spacing). Fertilizers (Azofosca - 16:16:16) were introduced in the spring under pre-sowing cultivation. The

green mass was harvested during the onset of the ripeness of the cereal component (the inflorescence emerge - beginning of the earing).

The technology of cultivation of mixed agrophytocenoses is common in the forest-steppe of the Middle Volga region. The precursor is barley. The subject of the research were zoned varieties and hybrids: the annual white sweet clover - Povolzhsky, the Sudan grass - Luninskaya, the corn - Katerina SV, the foxtail millet - Atlant, the sawa millet - Krasava, amaranth - Kizlyarets. Norms of sowing of crops in pure form (million of the emergent seeds per 1 hectare): white sweet clover - 6,0; Sudan grass - 4.0; corn - 0.12; sawa millet - 6.0; foxtail millet - 6,0; amaranth - 1.0.

EXPERIMENTAL PART

In the formation of the yield of agrophytocenosis an important role belongs to the competitive relationship between plants. Phytocenotic competition is a regime of scarcity of material and energy resources created by the absorption of all of the individuals included in the phytocenosis, as well as the reverse effect that this deficit regime has on them [6]. The most convenient criterion for assessing the intensity of competitive relations is the degree of change in the productivity of individual plants or their populations [9]. To evaluate the criterion of competitiveness, we used the Competitive ratio (CR), which was proposed by Willey, Rao (1980) [13].

$$CR_{AB} = \frac{Y_{AB}}{Y_{AA} * Z_{AB}} : \frac{Y_{AB}}{Y_{BB} * Z_{BA}}$$

where CR_{AB} – coefficient of competitiveness of culture A in mixture with culture B;
Y_{AB} - productivity of culture A in mixed crops with culture B, t / ha;
Y_{BA} - productivity of culture B in mixed crop with culture A, t / ha;
Y_{AA} - productivity of culture A in pure sowing, t / ha;
Y_{BB} - productivity of culture B in pure crop, t / ha;
Z_{AB} - the ratio of culture A in the mixture,%
Z_{BA} - the ratio of culture B in the mixture,%

It is established that the coefficient of competitiveness of the components of mixtures depended on the biological characteristics of plants, the rate of seeding of components in the mixture and the background of mineral nutrition. The concentration of protein in the mixture feed primarily depends on the content of the leguminous component, so it is necessary to provide agronomical measures to ensure a sufficiently high content of sweet clover in the mixture, i.e. CR of sweet clover in the mixture should be high. A higher CR value in the sweet clover was recorded in average for three years in a mixture with corn at a ratio of 70 + 40% - 2.21 units, in a mixture with foxtail millet - 1.30 units. (without fertilizer application) (Table 1).

Table 1: Competitiveness (CR) of annual crops, depending on the norm of sowing components and the background of nutrition (average for 2015-2017)

Mixture components	Sowing rate of components	Control		Background 1		Background 2	
		leguminous	concomitant	leguminous	concomitant	leguminous	concomitant
Sweet clover+Sudan grass	70+40%	1,00	1,00	0,75	1,33	0,47	2,11
Sweet clover+corn		2,21	0,45	1,77	0,57	1,25	0,80
Sweet clover +foxtail millet		1,30	0,77	1,02	0,98	0,62	1,61
Sweet clover +amaranth		0,80	1,25	0,65	1,54	0,60	1,67
Sweet clover+sawa millet		0,63	1,59	0,58	1,73	0,46	2,17
Sweet clover+Sudan	55+55%	0,35	2,88	0,28	3,52	0,19	5,35

grass							
Sweet clover+corn		0,75	1,34	0,69	1,45	0,47	2,11
Sweet clover +foxtail millet		0,50	2,02	0,40	2,52	0,25	4,08
Sweet clover +amaranth		0,33	3,02	0,27	3,74	0,22	4,62
Sweet clover+sawa millet		0,25	3,99	0,23	4,44	0,18	5,69
Sweet clover+Sudan grass	40+70%	0,11	9,41	0,07	13,89	0,05	20,47
Sweet clover+corn		0,33	3,07	0,21	4,80	0,15	6,79
Sweet clover +foxtail millet		0,18	5,44	0,15	6,85	0,08	12,41
Sweet clover +amaranth		0,12	8,54	0,10	10,35	0,08	12,64
Sweet clover+sawa millet		0,09	10,60	0,08	12,74	0,06	16,43

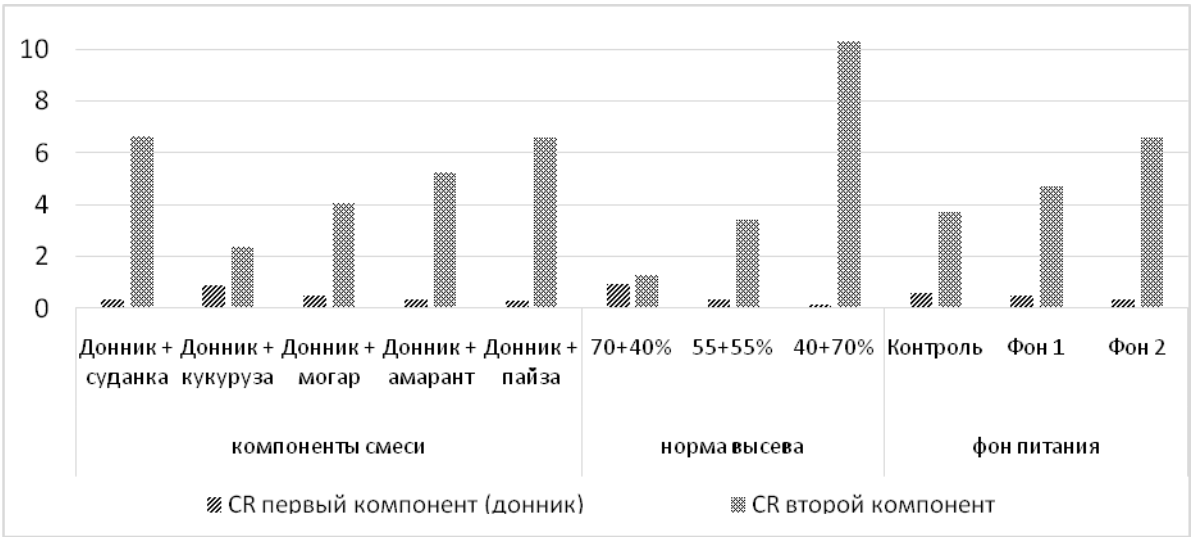

Figure 1: Competitive activity of the components of the mixture (on average by factors)

High indicators of competitiveness of sweet clover in a mixture with corn and foxtail millet indicate a weak competition between these plants and the expediency of their joint crops. The introduction of mineral fertilizers significantly reduced the CR index of the sweet clover against the background of 1 to 1.77 and 1.02 units. and against the background of 2 to 1.25 and 0.62 units, respectively.

Of the accompanying crops, Sudan grass and sawa millet mixed with sweet clover with a seeding rate of 40 + 70% - 9.41 and 10.60 units were remarkable for high indicators of competitiveness against the background without applying fertilizers, which is explained by their powerfully developed leaf surface and, as a result, strong shading and oppression of the sweet clover. The use of fertilizers significantly increased the share of Sudan grass and sawa millet in the yield of mixtures with sweet clover, which resulted in an increase in CR of these crops to 13.89 and 12.74 against the background 1 (at a seed rate of 40 + 70%) and 20.47 and 16.43 against the background 2 (at the same seeding rate), respectively.

It was revealed that a decrease in the rate of seeding of the clover in the mixture from 70% to 40% helps to reduce its competitiveness 6,7-9,0 times, while the CR of the concomitant component is increased 6.7-9.4 times.

On the average, the studied factors (independently of each other) revealed that sweet clover and maize, which CR amounted to 0.87 and 2.38, were the least competitive relative to each other (Fig. 1). This fact

is due to the same photoperiodism and growth rates of the aboveground mass in different phases of development of these crops. Further, as the intensity of competitive relations increases, mixtures are made - sweet clover + foxtail millet (CR 0.5 and 4.08), sweet clover + amaranth (CR 0.35 and 5.26), sweet clover + Sudan grass (CR 0.36 and 6.66) and sweet clover + sawa millet (CR 0.28 and 6.60), respectively. The increase in the value of CR of accompanying crops is associated with an intensive increase in their leaf area (especially Sudan grass and sawa millet), beginning with the tubing phase, and shading of the sweet clover plants.

A significant influence on the coefficient of crop competitiveness in mixed agrophytocenoses was provided by the rates of sowing of the components. With a high seeding rate (70 + 40%), the minimum intensity of competitive relations was 0.94 (sweet clover) and 1.30 (concomitant component), which is explained by the rather high density of the stalk of the sweet clover plants and the insignificant influence of the accompanying components on it at the given seeding rate. With equal seeding rates (55 + 55%), the competitive activity of the concomitant component significantly increases to 3.39, while the CR of the sweet clover decreased to 0.36. Concomitant component CR reaches its maximum values - 10.29, reach a minimum seeding rate of 40 - 70%, whereas the CR of the sweet clover is only 0.12.

The use of mineral fertilizers also significantly influenced the productivity of the studied mixtures, and, first of all, the accompanying components (bluegrass fodder crops and amaranth). Therefore, with increasing doses of fertilization, a decrease in the CR of sweet clover was noted from 0.60 in the control variant, up to 0.48 with application of N45R45K45 and up to 0.34 when N60P60K60 was introduced, while the CR of the concomitant component increased simultaneously from 3.69 to 4.70 and 6,60, respectively. This is due to the better reaction of the bluegrass fodder crops and amaranth to the introduced mineral nitrogen - their leaf surface, plant height has increased significantly. At the same time, there were no reliable biometric changes in the sweet clover plants when fertilizers were introduced.

To assess the criterion of the biological effectiveness of mixed crops, the land equivalents ratio (LER) was used. With its help, the calculation of the land unit is done which is needed to obtain in a pure crop sowing that number of each crop, which is formed on a unit area of mixed crops.

$$LER = \frac{Y_{AB}}{Y_{AA}} + \frac{Y_{AB}}{Y_{BB}}$$

where LER - the ratio of the ratio of land equivalents;
Y_{AB} - productivity of culture A in mixed crops with culture B, t / ha;
Y_{BA} - productivity of culture B in mixed crop with culture A, t / ha;
Y_{AA} - productivity of culture A in pure crop, t / ha;
Y_{BB} - productivity of culture B in pure crop, t / ha.

The value of the coefficient of biological effectiveness of annual mixtures was influenced by all the factors studied. The most effective mixtures are sweet clover + maize (against the background without applying fertilizers and when applying $N_{45}P_{45}K_{45}$, as well as at any seeding rates), the LER (total) value of which exceeded 1 unit, which indicates its productivity advantage over pure sowings of these crops 2). Against the second background (introduction of $N_{60}P_{60}K_{60}$), the mixture of sweet clover + amaranth is more effective, LER (total) of a mixture was 0.98-1.09.

The decrease in the seeding rate of the leguminous component in the mixture from 70 + 40% to 40 + 70% against the background without fertilizers did not lead to a change in the LER (total) index, as when the LER index of the leguminous component decreased (from 0.35-0.73 at the seeding rate 70 + 40% to 0.16-0.48 at the seed rate of 40 + 70%), the LER index of the concomitant component increased simultaneously (from 0.58-0.85 at the seeding rate of 70 + 40% to 0.83-1.03 at the seeding rate of 40 + 70%).

Studying the land equivalents ratio (LER) for each factor separately (independently of other factors) allowed us to establish that the mixture of sweet clover with corn has the greatest biological efficiency - LER (total) 1.14 (Figure 2). This means that in order to form a yield of agrocenosis this option requires 14% less area than one-species sowings of the same crops.

ISSN: 0975-8585

Table 2: Land equivalents ratio (LER) of annual agrophytocenosis at various rates of seeding components in the mixture and background of mineral nutrition (average for 2015-2017)

Mixture components	Sowing rate of components	Control			Background 1			Background 2		
		leguminous	concomitant	total	leguminous	concomitant	total	leguminous	concomitant	total
Sweet clover+ Sudan grass	70+40%	0,37	0,65	1,03	0,29	0,67	0,96	0,19	0,69	0,88
Sweet clover+corn		0,73	0,58	1,31	0,57	0,56	1,13	0,40	0,57	0,97
Sweet clover +foxtail millet		0,46	0,62	1,08	0,37	0,63	0,99	0,25	0,70	0,95
Sweet clover +amaranth		0,35	0,77	1,13	0,28	0,76	1,05	0,25	0,73	0,98
Sweet clover+sawa millet		0,31	0,85	1,16	0,24	0,73	0,97	0,19	0,72	0,91
Sweet clover+Sudan grass	55+55%	0,27	0,77	1,04	0,22	0,77	0,98	0,14	0,76	0,90
Sweet clover+corn		0,54	0,73	1,27	0,45	0,65	1,10	0,31	0,65	0,96
Sweet clover +foxtail millet		0,36	0,73	1,09	0,28	0,71	1,00	0,19	0,77	0,96
Sweet clover +amaranth		0,29	0,87	1,16	0,23	0,86	1,09	0,18	0,82	1,00
Sweet clover+sawa millet		0,24	0,94	1,18	0,18	0,80	0,98	0,14	0,81	0,95
Sweet clover+ Sudan grass	40+70%	0,16	0,88	1,04	0,11	0,87	0,98	0,07	0,85	0,92
Sweet clover+corn		0,48	0,84	1,31	0,32	0,87	1,19	0,22	0,85	1,07
Sweet clover +foxtail millet		0,27	0,83	1,09	0,20	0,80	1,00	0,12	0,86	0,98
Sweet clover +amaranth		0,20	1,00	1,20	0,17	1,00	1,17	0,13	0,96	1,09
Sweet clover+sawa millet		0,17	1,03	1,20	0,12	0,87	0,99	0,10	0,89	0,99

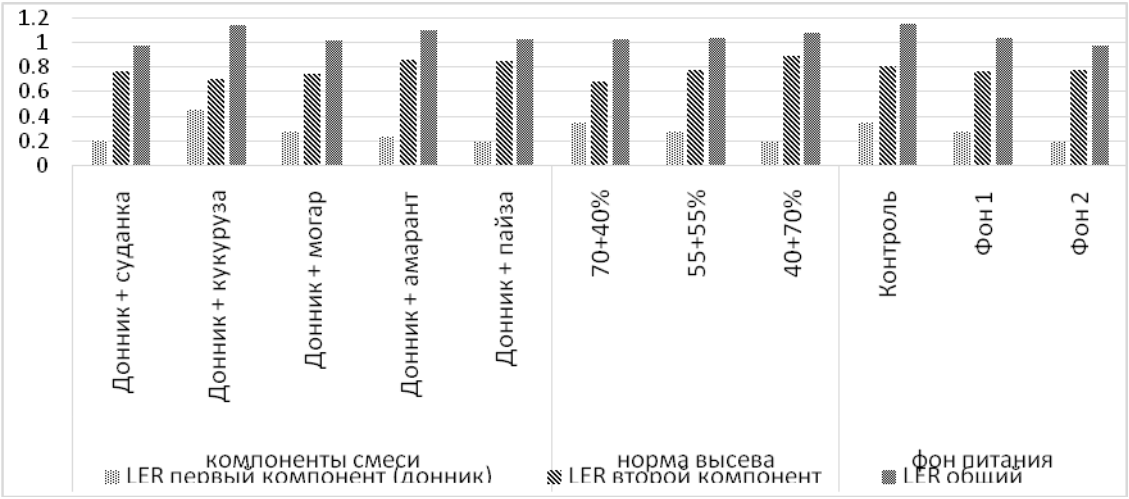

Figure 2: Land equivalents ratio (LER) of annual agrocenoses (on average by factors)

Further, as the biological efficiency decreases, the mixture of sweet clover with amaranth - 1.10, sweet clover with sawa millet and sweet clover with foxtail millet - 1.03 and 1.02 is located. The mixture of sweet clover with Sudan grass is the least effective, LER (total) was less than 1.0 (0.97).

The study of factor B (seed rate) independently of other factors allowed to set a small advantage of the seed rate of 40 + 70% in terms of biological efficiency (LER 1.08) over the seeding rate of 70 + 40% (LER 1.03) and seeding rate 55 + 55% (LER 1.04). At the same time, with a decrease in the seedling rate (from 70 + 40% to 40 + 70%), a decrease in the LER index (from 0.35 to 0.19) was noted with a simultaneous increase in the LER index of the concomitant component (from 0.68 to 0.89) .

The nutrition background (factor C) also influenced the coefficient of biological efficiency. More biologically effective - LER> 1 were mixtures cultivated without fertilizers (LER 1.15) and against the background of application of $N_{45}P_{45}K_{45}$ (LER 1.04). The use of mineral fertilizers in a dose of $N_{60}P_{60}K_{60}$ did not lead to an increase in the biological effectiveness of crops, the LER index decreased compared to the control up to 0.97.

CONCLUSIONS

The analysis of the competitiveness indicators of annual agrophytocenosis allowed to establish the most optimal components for the white sweet clover - corn and foxtail millet. The high biological efficiency of cultivating mixes of sweet clover with corn and amaranth at seeding rates of 40 + 70% (from the full seeding rate) against the background without the use of mineral fertilizers was found (LER was 1.31 and 1.20).

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